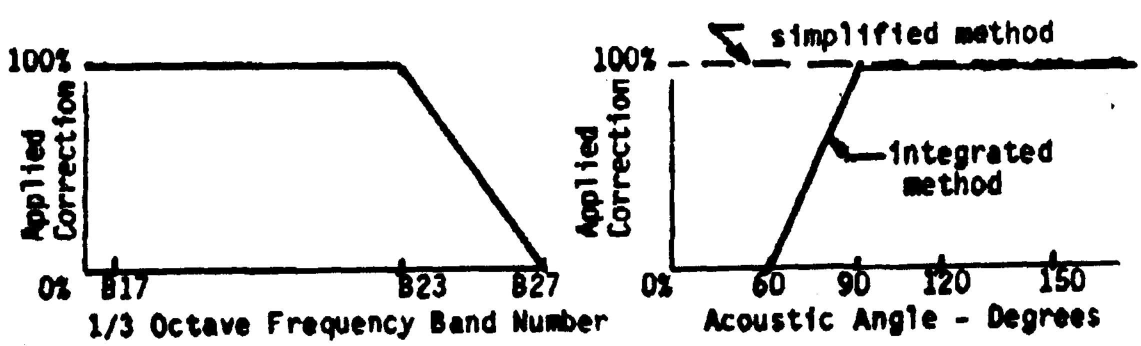
APPENDIX 1. NOISE DATA CORRECTIONS
FOR TESTS AT HIGH ALTITUDE TEST SITES

1. INTRODUCTION. Jet noise generation is somewhat suppressed at higher altitudes due to the difference in the engine jet velocity and jet velocity shear effects resulting from the change in air density. Use of a high altitude test site for the noise test of a model that is primarily jet noise dominated should include making the following corrections. The following source jet noise corrections are in addition to the standard pistonphone barometric pressure correction (about 0.3 dB/1000 feet pressure attitude) which is normally used for test sites not approximately at sea level, and applies to tests conducted at sites at or above 1200 feet mean sea level (MSL).

2. JET NOISE SOURCE CORRECTION. Flight test site locations at or above 1200 feet MSL, but not above 4000 feet MSL, may be approved provided the following criteria and source noise corrections are included in the requirements. Alternative criteria or corrections require the approval of AEE.

a. Criteria. Source jet noise altitude corrections from Figure 1-1 are required for each one-half second spectrum when using the integrated procedure and at $PNLT_{max}$ spectrum when using the simplified procedure (see section A36.11(f))applied per the following criteria:

Figure 1-1



b. Correction Procedure: An acceptable jet noise source correction is as follows:

(1) Correct each one-half second spectrum (or $PNLT_{max}$ one-half second spectrum, as appropriate) for the test airport altitude using the criteria of para. (a) above and,

$$\Delta SPL = 10 \log (d_R/d_T) + 50 \log (C_T/C_R) + 10k \log (U_R/U_T)$$

Where: d is atmospheric density in lbs/ft^3
C is speed of sound in fps
U is equivalent relative jet velocity in fps
k = 8, unless an otherwise empirically derived value is substantiated
Subscript R denotes Part 36 reference conditions:
sea level, $77^{o}F$, 70% RH, $RN1_{TEST}$, Va_{REF}
Subscript T denotes test conditions at test airport (or site): MSL altitude, ISA+10^{o}, 70% RH, $RN1_{TEST}$, Va_{TEST}
U = Ve - Va, where:
Ve is the equivalent jet velocity as defined in SAE ARP-876C, Appendix C (May 1983) and obtained from the engine cycle deck in fps
Va is aircraft velocity in fps
RN1 is corrected RPM $(N_1/\sqrt{\theta_{T2}})$

(2) For each one-third octave band SPL, arithmetically add the altitude jet noise correction (Item (1)) to the measured SPLs to obtain the altitude source jet noise corrected SPLs for section B36.3(a) Step 1, of Part 36.

(3) The above altitude correction is to be applied to all measured test data including approach conditions (unless it can be substantiated that the jet noise during approach does not contribute significantly to the total aircraft noise).

APPENDIX 2. GUIDANCE MATERIAL ON METHODS TO ACCOUNT FOR THE EFFECTS OF BACKGROUND NOISE ON AIRPLANE RECORDED NOISE DATA

1. INTRODUCTION.

a. The following information on methods for removing the effect of background noise on measured recorded airplane sound pressure level data is provided as guidance material for the certificate applicant.

b. Sound measurement and analysis system dynamic range performance limitations can result in measured sound pressure levels that are influenced by the presence of background noise. This problem occurs primarily at high frequencies where airplane noise source characteristics and atmospheric absorption result in low one-third octave band sound pressure levels relative to those of the lower frequency portion of the spectrum.

c. The influence of background noise on recorded sound pressure level data may be unavoidable and, in some instances, correction of recorded sound pressure level data may be required.

d. The application of the data correction methods presented in this guidance material will provide an acceptable estimate of sound pressure level data that would have been measured in the absence of background noise. Approval for the use of other correction procedures may be requested by certificate applicants, and approval for the use of any procedure remains with the certificating authority.

2. BACKGROUND NOISE.

a. The lowest level of true airplane sound pressure levels measured during a flyover test may be limited by background noise. Background noise is established by the test site ambient sound and electrical noise of the measurement system (predetection noise). The predetection ambient sound will add, on an energy basis, to the true aircraft noise. In addition, the dynamic range of the analysis equipment may establish the lowest possible readout value for any one-third octave band level (post detection background noise).

b. The background noise level is defined as the mean predetection level or the post detection level, whichever is the greater. For the purposes of the corrections described in this appendix, the background noise level is defined as the mean predetection level plus 3 dB, or the post detection level plus 1 dB, whichever is greater.

c. The ambient sound and electrical noise of the measurement system should be determined in accordance with requirements of Part 36 and this AC.

3. CORRECTION PROCEDURES.

a. Where the airplane sound pressure level is greater than the background noise level, the true airplane sound pressure level may be estimated by subtracting, on an energy basis, the predetection level from the total measured sound pressure level. No correction for post detection noise is required if measured sound pressure levels exceed the post detection noise level.

b. Where measured sound pressure levels are equal to or less than the background noise level, the airplane sound pressure levels are defined as being masked.

c. When the tone is not masked and if no more than the four highest frequency one-third octave bands within one second of PNLTmax are masked, use the frequency extrapolation method below.

d. If more than the four highest frequency one-third octave bands are masked, then the sound pressure levels for the masked bands may be determined by applying one or more of the correction procedures described below.

e. Time Extrapolation (7-12 bands).

(1) This procedure can be applied to measured data where more than seven but less than twelve of the highest one-third octave bands are masked during only a portion of the sound measurement period.

(2) Corrections in the time domain are made by taking into account propagation distance (spherical divergence and atmospheric absorption) relative to the first (approaching) or last (receding) unmasked sound pressure level measurement in the one-third octave band requiring correction. Source directional characteristics in each masked frequency band may be assumed to be:

(a) Directional, as supported by test data, or

(b) Omnidirectional.

Note: Preference should be given to test data.

f. Frequency Extrapolation (4-7 bands). Sound pressure levels in each of up to seven masked high frequency one-third octave bands may be estimated by extrapolating the highest unmasked frequency band by an amount equal to the sum of source spectrum slope and the atmospheric absorption in each frequency band along the sound propagation path from source to measurement location. The source high-frequency spectrum slope is defined by:

(1) the missing portions of the spectrum shall be assumed to have at the source the decibel value of the highest valid one-third octave band; or

(2) a slope supported by test data, acquired from closer-in microphones or static engine noise measurements.

Note: Preference should be given to test data.

g. In those cases where masked band(s) occur between unmasked bands, the measured sound pressure levels in the masked band(s) should be used, or other values as supported by applicant's data. In the case where one masked band is located between two unmasked bands, the mean value of the adjacent unmasked bands may be ascribed to the masked band, if this mean value is lower than the measured level in the masked band.

h. No penalty for spectral irregularities resulting from the correction procedure is ascribed to those masked frequency bands that have been corrected for the effects of ambient noise, provided that it can be shown that no engine tone occurred in the masked bands.

APPENDIX 3. GUIDANCE MATERIAL ON METHODS TO IDENTIFY PSEUDOTONES/ FICTITIOUS TONES IN AIRPLANE RECORDED NOISE DATA

1. INTRODUCTION.

a. The following information on methods for identifying pseudotones/ fictitious tones in airplane sound measurements is provided as guidance material for the certificate applicant.

b. Airplane sound measured at 1.2 m (4 ft) above the ground should be composed of broadband noise superimposed with spectral irregularities. The spectral irregularities may be caused by actual airplane/engine tones, ground plane reflections or atmospheric propagation effects. In addition, spectral irregularities may be artificially created by data processing techniques which account for ambient sound and atmospheric absorption corrections.

c. The application of a tone correction factor in the computation of EPNL accounts for the subjective response due to the presence of pronounced spectral irregularities. Tones generated by airplane noise sources constitute the spectral irregularities requiring application of tone correction factors.

d. The application of pseudotone/fictitious tone identification methods presented in this guidance material should provide an acceptable means of identifying spectral irregularities not requiring application of tone correction factors. Approval for the use of other correction procedures may be requested by certificate applicants and approval for the use of any procedure remains with the certificating authority.

2. SPECTRAL IRREGULARITIES.

a. Discrete frequency tones generated by airplane noise sources set the measured spectral irregularities requiring application of tone correction factors.

b. Spectral irregularities occur in data measured at 1.2 m (4 ft) due to interference effects caused by the reflection of sound from the ground surface. These ground reflection effects, known as pseudotones, are most pronounced at low frequencies. Any other spectral irregularity not related to aircraft noise sources, such as those caused by atmospheric propagation effects, are termed fictitious tones. Spectral irregularities producing fictitious tone correction factors may result from corrections applied to the measured sound pressure level data due to:

(1) masking of sound pressure levels, or

(2) differences between test and reference sound attenuation in the 4.0 kHz and 5 kHz one-third octave bands (as prescribed in SAE ARP 866A). Neither fictitious tones or pseudotones are related to aircraft noise sources and, therefore, need to be identified so that tone correction factors are not applied.

c. Pseudotones in the 800 Hz and lower one-third octave bands may be excluded from the calculation of corrections for spectral irregularities. To qualify for this exclusion, the pseudotones should be clearly identified using one of the methods outlined below. Pseudotones at frequencies above 800 Hz generally should not yield significant tone corrections. However, for consistency, each tone correction value should be included in the computation for spectral irregularities.

d. If fictitious tones are identified (using one of the methods outlined in paragraph 3), a revised value for the background sound pressure level should be determined and used to compute a revised tone correction factor for that particular one-third octave band.

3. METHODS FOR IDENTIFICATION OF PSEUDOTONES/FICTITIOUS TONES.

a. Narrowband Analysis. By analyzing the measured data using a filter with a bandwidth narrower than one-third of an octave, the presence or absence of airplane or engine generated discrete frequency tones may be determined.

b. Frequency Tracking of Spectral Irregularities During the Flyover. Because of Doppler shift, the observed frequencies of airplane noise sources progressively decrease as the airplane approaches the point of acoustic overhead and then continue to decrease as the airplane moves away from overhead.

$$f_{\text{Doppler shifted}} = \frac{f_{\text{source}}}{1 - M \cos \theta}$$

where

f = frequency
M = Mach number
θ = angle between the flight path and a line connecting the source and observer at the time of noise emission.

Ground reflection effects on the spectra also decrease in frequency as the airplane approaches the acoustic overhead; however, in contrast to the Doppler shift effect, the ground reflection effects increase in frequency after overhead. These differing characteristics can be used to separate source and reflection effects. An effective method of presenting this information is shown in Figure 1.

c. Microphone Arrangement. Pseudotones may be identified by comparing measurements from 1.2 m (4 ft) microphone with corresponding data from an adjacent microphone which is:

(1) mounted near (within one-half microphone diameter or one-quarter wavelength of the highest frequency to be recorded, whichever is least) a hard reflecting ground surface, or

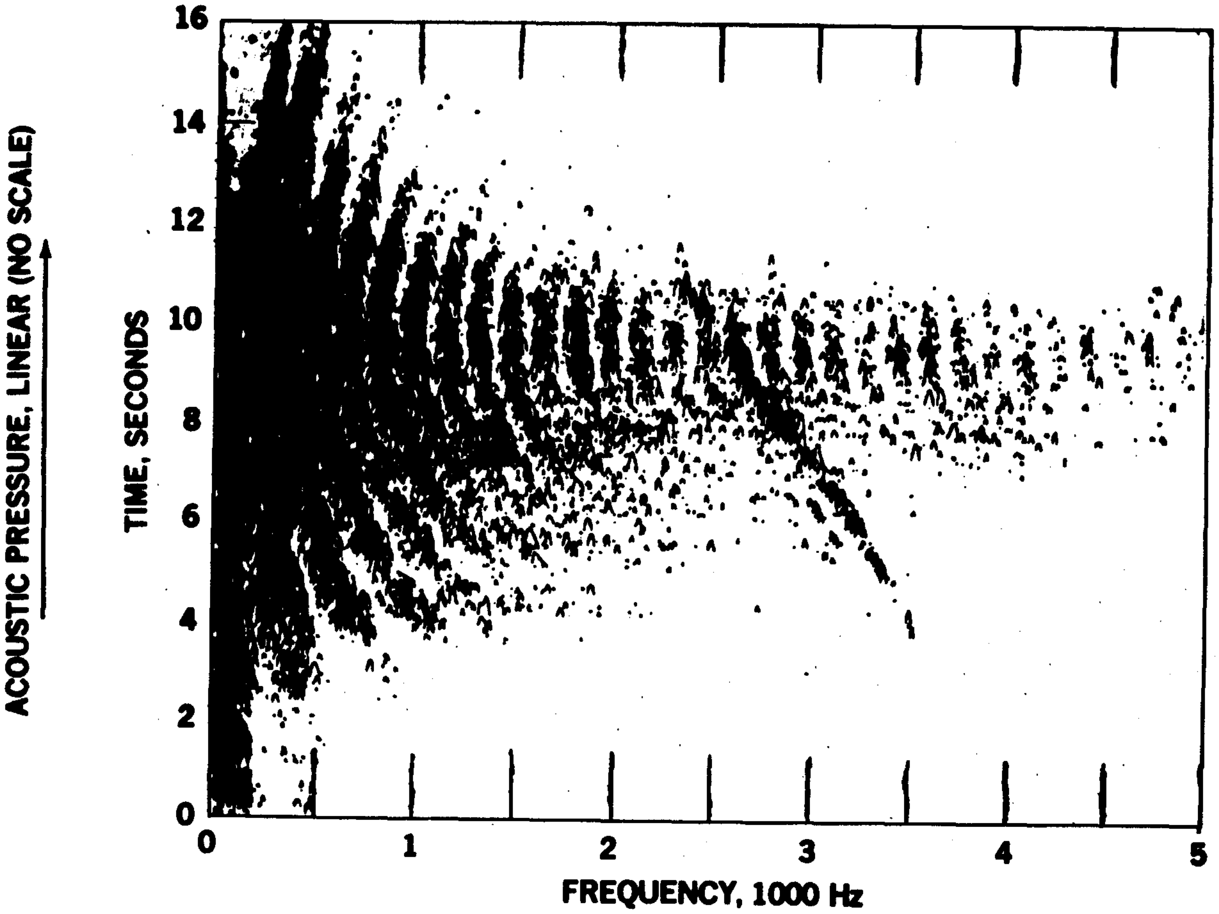
(2) raised to a height above the ground surface so that the first interference dip falls below the range of interest (50 Hz). Microphones at 10 m (33 ft) have been used.

Using either microphone arrangement eliminates the interference irregularities from the low frequency range of the measured spectra and when a comparison is made between the two data sets, airplane source tones can be separated from any pseudotones that may be present.

d. Inspection of Noise Time Histories. Spectral irregularities which produce fictitious tone correction factors will usually occur in the 1 kHz to 10 kHz frequency range. Depending upon the variation with frequency of the tone correction calculation procedure, the magnitude of these tone corrections typically ranges from 0.2 to 0.6 dB. PNL and PNLT time histories with constant level differences indicates invalid fictitious tone corrections. This analysis may be supplemented by narrowband analysis to demonstrate that these characteristics do not result from the Doppler shift effect.

FIGURE 1

3-D SHADOWGRAPH SHOWING PSEUDOTONES (CURVED LINES)
CAUSED BY GROUND REFLECTION INTERFERENCE
AND ACTUAL ENGINE TONE (STRAIGHT LINE)

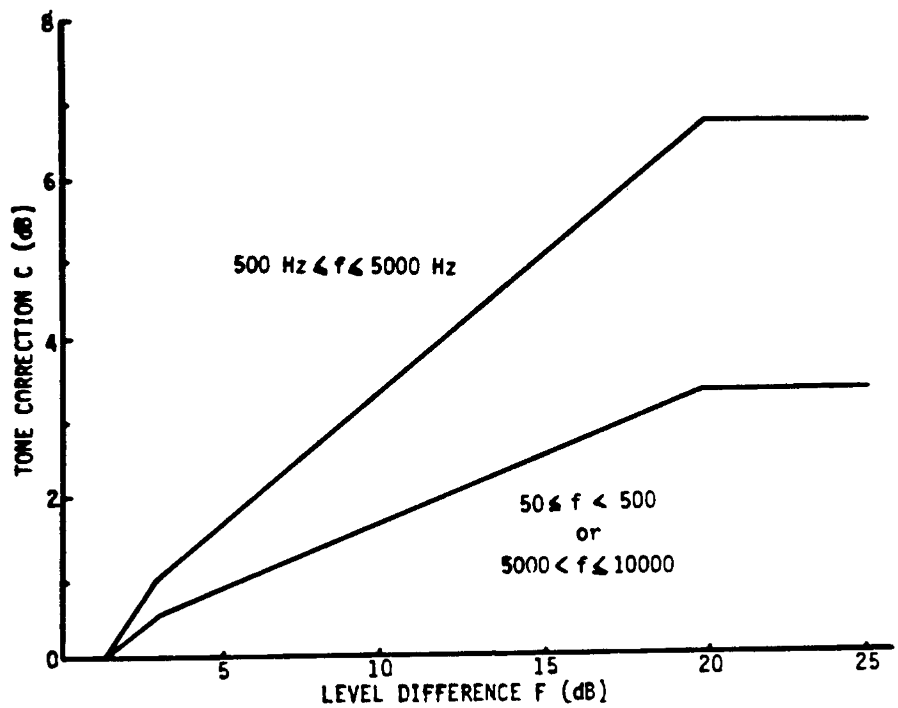


APPENDIX 4. COMPUTATION OF EFFECTIVE PERCEIVED NOISE LEVEL (EPNL)

1. **EPNL should be computed by the methods prescribed in Part 36, Appendix B. In the computation, noise having pronounced spectral irregularities should be** adjusted by a tone correction factor (see section B36.5). An approved tone correction factor may be determined from the sound pressure level differences (f(i,k)) and Table 1. All other procedures in the computation of EPNL are the same as Part 36, Appendix B.

Appendix 4

TABLE 1 - TONE CORRECTION FACTORS



FREQUENCY f (Hz)	LEVEL DIFFERENCE F (dB)	TONE CORRECTION C (dB)
50 ≤ f < 500 or 5000 < f ≤ 10000	0 < F < 1.5	0
	1.5 ≤ F ≤ 3.0	(F -1.5)/3
	3.0 < F < 20.0	F/6
	20.0 ≤ F	3 1/3
500 ≤ f ≤ 5000	0 < F < 1.5	0
	1.5 ≤ F ≤ 3.0	(2F - 3)/3
	3.0 < F < 20.0	F/3
	20.0 ≤ F	6 2/3

APPENDIX 5. GUIDANCE MATERIAL ON METHODS TO CALCULATE CONFIDENCE INTERVALS

1. **INTRODUCTION.** The use of NPD maps requires confidence intervals to be determined using a more general formulation than used for a cluster of data points. For this more general case, confidence intervals should be calculated about a regression curve for flight test data and for static test data. These confidence intervals should be used in calculating the confidence intervals for the pooled data sets that constitute NPD maps.

2. **CONFIDENCE INTERVAL FOR THE MEAN OF CLUSTERED DATA.**

Let L = data (EPNL)

N = number of data points

K = order of regression curve
(K = 0 for clustered data)

v = degrees of freedom = N - K - 1

t = Student's t distribution for 90 percent confidence interval and v degrees of freedom

for example:

t = 2.015 for N = 6 (v = 5)
t = 1.645 for N = infinity

$$\bar{L}\text{ (mean)} = \frac{\sum_{1}^{N} L_i}{N}$$

$$S\text{ (standard deviation)} = \sqrt[2]{\frac{\sum_{1}^{N}(L_i - \bar{L})^2}{N-1}} = \left[\frac{N\sum_{1}^{N} L_i^{\,2} - \left(\sum_{1}^{N} L_i\right)^2}{N(N-1)}\right]^{1/2}$$

$$CI\text{ (confidence interval)} = \pm\, t\,\frac{S}{\sqrt{N}}$$

3. CONFIDENCE INTERVAL FOR A MEAN REGRESSION CURVE.

The general expression for a regression curve may be written as:

$$EPNL = a_o + a_1X + a_2X^2 + \ldots \quad a_kX^k$$

where EPNL = noise level
X = parameter such as EPR, RPM, altitude, etc.
a = coefficients for the regression curve
k = polynomial order of regression curve

define: ΔEPNL = difference between regression curve and individual data point (X constant)
N = number of data points
v = degrees of freedom = N - k -1
t = students t distribution for 90 percent confidence interval

$EPNL_o$, X_o = a particular point on the regression curve
CI_o = confidence interval for a particular point

For a linear (k = 1) regression, the equation is as follows:

$$CI_o = \pm\, t \sqrt[2]{\frac{\sum_{1}^{N} (\Delta EPNL)^2}{N-K-1}} \sqrt[2]{\frac{1}{N} + \frac{(X_o - \bar{X})^2}{\sum_{1}^{N} (X_i - \bar{X})^2}}$$

$$\text{where } \bar{X} = \frac{\sum_{1}^{N} X_i}{N}$$

Note: k is normally limited to k = 2. k = 3 may be approved when there is a physical basis for that polynomial order of curve fit.

For a higher order regression curve, a particular $EPNL_o$ is:

$$EPNL_o = a_o + a_1 X_o + a_2 X_o^2 + \ldots + a_K X_o^K$$

For higher order regression curves, the regression coefficients are usually calculated using computer-matrix solutions, since there are many terms.

Defining the vectors: $X_o' = \begin{bmatrix} 1 & X_o & X_o^2 & \ldots & X_o^k \end{bmatrix}$ a row vector

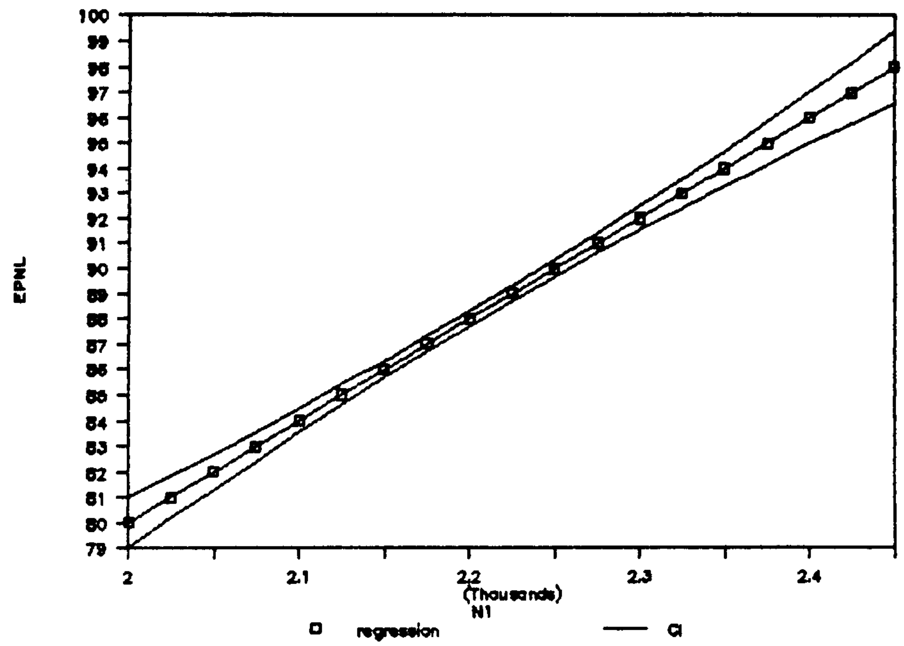
$$X_o = \begin{bmatrix} 1 \\ X_o \\ X_o^2 \\ \cdot \\ \cdot \\ \cdot \\ X_o^k \end{bmatrix}$$ a column vector

and $\delta^2 A^{-1}$ = the varience-covarience matrix for the a_K values

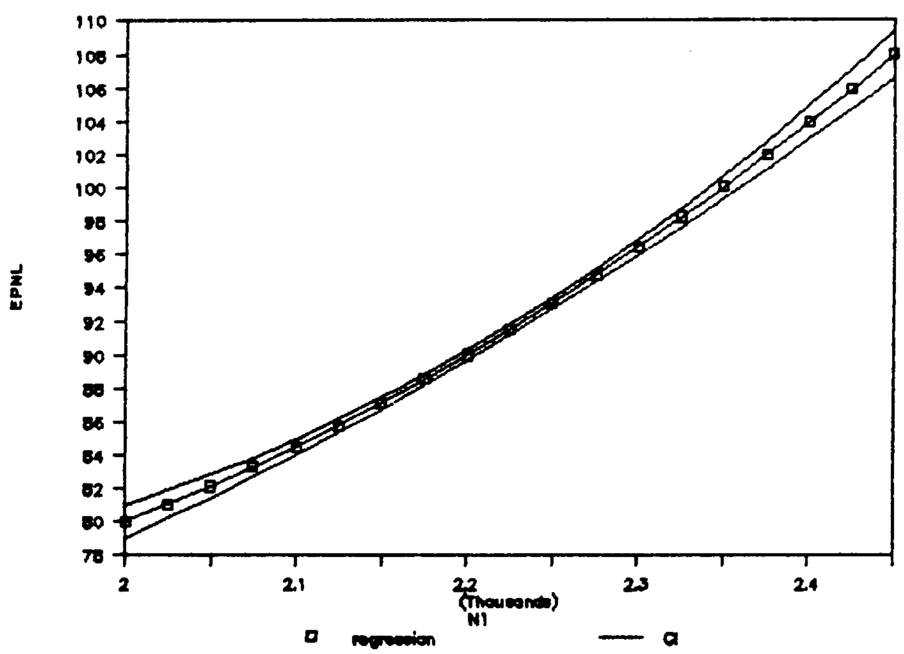
Then the 90 percent confidence interval for a particular noise level, $EPNL_o$, on a regression curve of EPNL vs. X is:

$$CI_o = \pm\, t \sqrt[2]{\frac{\sum_{1}^{N} (\Delta EPNL)^2}{N-K-1}} \sqrt[2]{X_o' A^{-1} X_o}$$

Linear Example



Quadratic Example



4. CONFIDENCE INTERVAL FOR POOLED DATA SETS.

The confidence interval for pooled data sets may be calculated as follows. For example, for three data sets (flight test data and two different static tests) - each with its own confidence interval:

let $ZZ_i = (CI_i/t_i)^2$ (square of the confidence interval without the Student's t term for each data set)

then for three data sets, the confidence interval for the pooled data is:

$$CI_o = +/- t' (ZZ_1 + ZZ_2 + ZZ_3)^{1/2}$$

$$\text{where } t' = \frac{ZZ_1 t_1 + ZZ_2 t_2 + ZZ_3 t_3}{ZZ_1 + ZZ_2 + ZZ_3}$$

5. REFERENCES

(a) Kendall, M. G. and Stuart, A., The Advanced Theory of Statistics, Volumes 1 and 2, Hafner, New York, 1973.

(b) Yule, G. U. and Kendall, M. G., An Introduction to the Theory of Statistics, 14th ed., Griffin, New York, 1950.

(c) Walpole, R. E. and Myers, R. H., Probability and Statistics for Engineers and Scientists, MacMillan, New Yoek, 1972.

(d) Cochran, W. G., "Approximate Significance Levels of the Behrens-Fisher Test," Biometrics, 20, 191-195, 1964.

(e) Snedecor, G. W. and Cochran, W. G., Statistical Methods, 6th ed., Iowa State University Press, Ames Iowa, 1968.

Table 5-1

STUDENT'S t DISTRIBUTION FOR 90 PERCENT CONFIDENCE INTERVAL

Degree of freedom (V)	t
1	6.314
2	2.920
3	2.353
4	2.132
5	2.015
6	1.943
7	1.895
8	1.860
9	1.833
10	1.812
12	1.782
14	1.761
16	1.746
18	1.734
20	1.725
24	1.711
30	1.697
60	1.671
∞	1.645

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